SECTION 15910 - DIRECT DIGITAL CONTROL SYSTEMS

***SPECIFIER S NOTE:** Insert wording, numbers, etc. as appropriate where [italics in parenthesis] are shown throughout this specification section. Italicized words are used for directions to the specifier and should be filled in. Blue colored text are Notes to Specifier and should be completely deleted from the final text. Red colored text is used for items to be modified. Maintain footer notation in italics with the current version used (e.g. TG15910 v00.03).*

***SPECIFIER NOTES:** This guide specification covers the requirements for direct digital control (DDC) of heating, ventilating, and air conditioning (HVAC) systems. The intent of this specification is to provide a multiloop, stand-alone, and distributed digital control system as manufactured by companies in the HVAC control field. This control system provides control of all HVAC control functions. Analog and digital (binary, on/off, open/close) control signals are input to microprocessor based digital controllers. The digital controllers perform the control logic and output analog and digital signals to the HVAC equipment.*

This control system will have interface ports to allow connection to a terminal, portable computer, and a central site computer. The interface equipment will not provide day to day control of the HVAC system, but it will allow the operator to enable and disable equipment, change setpoints, change operating schedules, receive trends and alarms, and allow uploading and downloading of control programs. This guide specification can be used to acquire a direct digital control system that consists of:

DDC of HVAC equipment with graphic operator work station. The operator work station can be located in the building (directly connected to a communications LAN) or at a remote site (connected to the digital controller through a LAN or modems and a telephone line).

The DDC systems should have laptop computers that may be taken to the mechanical room for direct connection to the digital controllers.

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. Section 15050, Basic Mechanical Materials and Methods, applies to this section, with the additions and modification specified herein.

1.02 DEFINITIONS

A. BACnet - BACnet is a standard communication protocol under development by the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE). The controller manufacturer shall have a company policy to support the implementation of BACnet.

B. Digital Controller - A control module which is microprocessor based, programmable by the user, has integral I/O, and performs stand-alone operations.

C. Direct Digital Control (DDC) - A digital controller as defined in this document. The controller directly senses building environment and makes control decisions based on user defined, controller resident programs. The controller outputs control signals that directly operate valves, dampers, and motor

controllers. No conventional control devices, pneumatic or electronic, such as receiver-controllers, thermostats, and logic units are present within or interface with a direct digital control loop. Actuators are electric or pneumatic, and the controller output is converted to the appropriate type of signal.

D. DDC System - A system made up of one or more digital controllers. Required climate control and energy management functions for complete operation of an HVAC system are provided by DDC from digital controllers. No conventional control devices (pneumatic or electronic) such as receiver-controllers, thermostats, and logic units are used. Digital controllers in a system are linked in a communication network composed of one or more levels of local area networks (LAN).

E. Distributed Control - The intent of distributed control is to install the controllers near the equipment being controlled, and to distribute the processing to each stand alone DDC panel. The control system is built up of stand-alone controllers, utilizing sensor inputs and control outputs.

F. Dynamic Control - A process that optimizes operation of HVAC systems (air handler units, converters, chillers, and boilers) by increasing and decreasing setpoints or starting and stopping equipment in response to heating and cooling needs of downstream equipment. A requirement of dynamic control is knowing the heating/cooling demand status of downstream equipment, therefore dynamic control requires controllers connected in a communications network.

G. Firmware - Firmware is software programmed into read only memory (ROM) and erasable programmable read only memory (EPROM) chips. Software may not be changed without physically altering the chip.

H. Graphic Sequence of Operation - A drawing or graphic showing all interlocks and control loop sequences between the input and output points. Graphic sequence of operation is a graphical representation of the sequence of operation. The graphic sequence of operation will show all inputs, outputs, and logic blocks.

I. Hand-Held Terminal - A hand-held terminal is a portable device, control system manufacturer-specific, which can be connected directly to a communications port on a digital controller and through which the digital controller can be interrogated and, in some cases, programmed.

J. Input/Output (I/O) - I/O refers to analog inputs (AI), digital inputs (DI), analog outputs (AO), and digital outputs (DO) in a digital controller. Inputs are from analog sensors (temperature, pressure, humidity, flow) and digital sensors (motor status, flow switches, switch position, and pulse output devices). Outputs operate modulating and on/off control devices.

K. I/O Unit - An I/O unit provides additional point capacity to a digital controller and communicate with the stand-alone digital controller on LAN. An I/O unit is not stand-alone because the control program does not reside in the I/O units microprocessor.

L. Integration - The ability of control system components to have interoperability between different manufacturers to connect together and provide coordinated control via real-time data exchange and control functions through a common communications data exchange protocol. Integration shall extend to the operator s workstation software, which shall support user interaction with all control system components. Methods of integration include industry standard protocols such as: BACnet, ARCnet, LonMark/LonTalk, OLE for Process Control (OPC) or integrator interfaces between cooperating manufacturer s systems.

M. Local Area Network (LAN) -
   1. A communications bus that interconnects digital controllers for peer-to-peer communications. Different levels of LANs are possible within a single DDC system. In this case a digital controller on a higher level LAN acts as a network controller to the controllers on the lower level LAN. The network controller, then, has at least two LAN communications ports. One port supports peer-to-peer communications with other digital controllers on the higher level LAN. The other port supports communications with the digital controllers on the lower level LAN.

   2. LANs permit sharing global information, make it possible to apply building wide control strategies such as peak demand limiting, permit dynamic control strategies, allow coordinated response to alarm conditions, and permit remote monitoring and programming of digital controllers.

   3. Facility-wide LAN refers to a commercially available local area network. These LANs allow the connection to an existing or new facility-wide LAN.

N. Microprocessor - A microprocessor refers to the central processing unit (CPU) that contains all the registers and logic circuitry that make it possible for digital controllers to do computing.

O. Open Protocol Bus (OPB) - A pre-programmed communications integrator that allows devices from one manufacturer to communicate and interact with those of another.

P. Open System Port (OSP) - A user programmable communications port that provides the ability to develop custom communications processes to integrate other operating systems with the DDC System.

Q. Output Signal Conversion - Output signal conversion refers to the changing of one kind of control output into a proportionally related signal appropriate for direct actuation of the controlled device. Signals are converted by a transducer which may be external to the digital controller originating the output.
   1. Examples in modulating control of pneumatic actuators are conversion of 4-20 ma signals into proportional 3-15 psig signals.

   2. An example of output signal conversion in on/off or open/close control is a contact closure originating in a digital controller which activates a solenoid air valve which passes main air, thereby forcing a damper to open fully.

R. Optimum Start - Optimum start is a method of starting the HVAC equipment prior to occupancy time in order to have the building at setpoint at occupancy. Optimum start shall be based on the zone temperatures, zone setpoints, and outdoor temperature. Optimum start will bring the zone to setpoint at occupancy time.

S. Peer-to-Peer - Peer-to-Peer refers to controllers connected on a communications LAN that act independently, as equals and communicate with each other to pass information which facilitates control.

T. PID - PID refers to proportional, integral, and derivative control; the three types of action that are used in controlling modulating equipment.

U. Resolution - Refers to the number of possible states an input value or output value can take and is a function of the digital controller I/O circuitry; the A/D converter for input and the D/A converter for output. Ten bit resolution has 1024 possible states and eight bit resolution has 256 possible states.

V. Stand-Alone Control - Refers to the digital controller being able to perform required climate control, and energy management functions without connection to another digital controller or central site computer. Digital controller requirements for stand-alone control are a time clock, a microprocessor, microchip resident control programs, PID control, a communications port for interfacing with and programming the controller, firmware for interrogation and programming, and I/O for sensing and effecting control of its control environment.

W. Terminal Control Unit (TCU) - An off-the-shelf, stand-alone digital controller equipped for communication on a lower level local area network. TCUs may deviate from stand-alone only in receiving energy management and time information from a stand alone digital controller. A TCU is commonly application specific and is used for distributed control of specific HVAC subsystems. A TCU communicates with the digital controllers. Typically, a TCU communicates on a lower level LAN. Examples where TCUs might be used to control of small air handling units (AHUs), variable air volume (VAV) boxes, fan coil units, and heat pumps.

X. Year 2000 Compliant -- means computer controlled facility components that accurately process date and time data (including, but not limited to, calculating, comparing, and sequencing) from, into, and between the twentieth and twenty-first centuries, and the years 1999 and 2000 and leap year calculations.

SPECIFIER S NOTE: If there is an existing DDC control system within the building or at the facility, list the manufacturer and describe on the Drawings and Specifications, the specific requirements for interfacing with the existing DDC system. If there is an existing DDC system and workstation, the new DDC system shall communicate with the existing workstation. The following paragraph A shall be edited by the Consultant.

1.03 DDC SYSTEM DESCRIPTION

A. OPERATOR INTERFACE: All new BACNET objects defined in this contract will be mapped to the existing [_____] (Trane Tracer or

Johnson Controls , etc) system user workstation. The [Trane Co. or Johnson Controls, etc] will perform all graphic creation and point mapping under a separate contract from the State. The successful bidder must provide BACNET object definitions and equipment to PICS information to the [_____ _____ _____ _____] (Trane Co. or Johnson Control, etc). Modifications of the existing system shall NOT reduce the existing systems capabilities.

1.04 SUBMITTALS - Submit the following:

A. Manufacturer s Catalog Data
   1. DDC hardware
   2. DDC capabilities
   3. Workstation software
   4. Input devices
   5. Output devices
   6. Surge and transient protection
   7. Laptop computer
   8. Hand-held terminal
   9. Panel mounted display and keypad

B. Equipment and software for which specification compliance data shall be submitted include but not limited to the following:
   1. DDC Hardware
      a. I/O; capable of supporting platinum RTD, precision thermistor, 4-20 ma, 0-10 VDC
      b. Programs will reside in microprocessor; controllers are stand-alone
      c. Communications ports; all communications ports as specified
      d. Protected memory; minimum hours required by this specification
      e. Operating temperature limits

   2. DDC Capabilities
      a. Communications; baud rate, communication ports, stand-alone
      b. Trending; capable of trending every point
      c. Alarming; capable of alarm generation as indicated
      d. Messages; as indicated
      e. Self diagnostics; identification of a failed module
      f. PID control; capable of PID control

SPECIFIER S NOTE: Delete this paragraph1.04.B.3 if a Workstation Software Package is not part of the contract.

   3. Workstation Software
      a. Mouse and keyboard operation
      b. Communications
      c. Program upload and download
      d. Dynamic point update
      e. Program modification
      f. Database modification
      g. Graphics and graphics modifications
      h. Penetration of graphics

   4. Input Devices
      a. Transmitters; accuracy, 4-20 ma, 0-10 VDC
      b. Temperature sensors; accuracy, stability, 100 percent factory screening, platinum RTD or thermistor

c. Humidity sensors; type of sensor, accuracy, range, and stability
d. Pressure sensor; accuracy
e. Flow or motor proof; type
f. Sensor wells; type

5. Output Devices
a. Dampers; types
b. Valves; types
c. Actuators.
d. Control Relays

6. External Surge and Transient Protection
a. Power line
b. Communications links and/or devices (between buildings)

C. Drawings - Submit the following drawings:
1. Control system schematic

D. Design Data - Submit test data demonstrating the following installed components will meet specification requirements.
1. Temperature sensor accuracy - Submit manufacturer specification of temperature sensor accuracy. Literature shall make clear sensor accuracy as specified.

2. Temperature sensor stability - Provide manufacturer specification of five year stability of RTDs and thermistors. Literature shall make clear sensor stability as specified.

E. Schedules
1. List of shop drawings

2. List of symbols and abbreviations used on shop drawings

3. List of I/O points - For each input and output physically connected to a digital controller provide, on a controller by controller basis, provide the following:
a. Point description: for example: mixed air temperature, supply fan start/stop, etc.
b Point type: AO, AI, DO, or DI.
c. Point range: 4-20 ma, 3-15 psi, platinum RTD resistance ohm, thermistor.
d. Sensor range associated with point range: for example 0-100 degrees F, 0-2 inches of water.
e. Software name(s) associated with point, if any.
f. Terminal number to which point is connected.

4. Equipment components list - Submit a listing of controllers and connected devices shown on control system schematic. List the following:

a. Control system schematic component name
b. Description
c. Manufacturer of controller
d. Controller s name

e. Equipment part numbers
f. Cv for valves
g. For actuators:
1) Motive force (such as pneumatic, or electric)
2) Normal position
3) Nominal operating range (such as 3-7 psi, 4-8 ma)

5. AC power table - Submit a table listing each controller and the circuit breaker number, panel box number, and physical location of each controller s source of AC power.

F. Statements
1. Contractors qualifications - Submit statements required in Part 1, Quality Assurance, Qualifications.

2. Training - Submit schedule, syllabus, and training materials in accordance with Part 3, EXECUTION.

G. Records - Provide administrative and closeout submittals:
1. Training course documentation - Training course documentation shall include a manual for each trainee plus two additional copies and two copies of audiovisual training aids, if used. Documentation shall include an agenda, defined objectives for each lesson and detailed description of the subject matter of each lesson.

2. Service organization - Qualified service organization list that shall include the names and telephone numbers of organizations qualified to service the HVAC control systems

3. Contractor certification - Provide certification that the installation of the control system is complete and the technical requirements of this section have been met.

H. Operation and Maintenance Manuals
1. Controls and HVAC System Operators Manual - Construct and provide a Control and HVAC Systems Operators Manual. This manual is designed to document the HVAC and control system. Construct this manual using a 3 ring binder with a minimum of the following 7 sections. Use tabs to divide each section.
a. Section 1. Description of HVAC Systems: Provide a description of the HVAC system components and control system. Include sequences of operation and a complete points list.
b. Section 2. Controls Drawings: Provide drawings as specified.
c. Section 3. Control Program Listings: Provide listing of all control programs, including terminal equipment controller setup pages.
d. Section 4. Current Operating Parameters: Provide printouts of input and output setup information, database setups. This section is intended to provide information such as point addresses, slopes and offsets for all points, database of points, etc.
e. Section 5. Design Information: Provide tab, but leave this section blank.
f. Section 6. Control Equipment Cut Sheets: Provide cut sheets of all controller hardware and accessories. Include temperature versus

resistance charts for temperature sensors, and calibration charts for pressure transducers.

g. Section 7. Control Program: Provide a fully operational control system disk (CD disk format preferred) identical to the original control program as installed. In addition, provide a restore - backup disk of the control program and backup copy of ACAD controls drawings on a 3.5 inch disk. It is understood that the software will be available to the base and used only for the buildings in this contract.

2. DDC Manufacturer s Hardware and Software Manuals -

3. Controls and HVAC System Operators Manual -
   a. Section 1. Installation and Technical Manuals for all digital controller hardware.
   b. Section 2. Installation and Technical Manuals for workstations.
   c. Section 3. Operators Manuals for all digital controllers.
   d. Section 4. Operators Manuals for workstations software.
   e. Section 5. Programming Manuals for all digital controllers.
   f. Section 6. Programming Manuals for workstation software.

1.05 STORAGE - Stored products shall be protected from the weather, humidity and temperature variations, dirt and dust, and other contaminants, within the storage condition limits published by the equipment manufacturer.

1.06 QUALITY ASSURANCE

A. General
   1. The Direct Digital Control (DDC) System herein specified shall be fully integrated and installed as a complete package by the Direct Digital Control System Contractor. The System shall include all wiring, piping, installation supervision, calibration, adjustments, and checkout necessary for a complete and fully operational system.

   2. The Direct Digital Control System Contractor shall be regularly engaged in the engineering, programming, installation and service of Direct Digital Control systems of similar size and complexity.

   3. The DDC Contractor shall have a local facility Oahu. Emergency service shall be available on a 24-hour, 7-day-a-week basis.

   4. The DDC Contractor shall be responsible for all work fitting into place in a satisfactory and neat workmanlike manner acceptable to the Owner/Architect-Engineer.

B. Experience Record -
   1. The DDC Contractor shall have a minimum of five years experience with the complete installation of Direct Digital Control systems of similar size and technical complexity. The DDC Contractor shall provide a list of three comparable projects that have Direct Digital Control Systems with the features as specified for this project. These projects must be on-line and functional.

2. The DDC Contractor shall employ specialists in the field of Direct Digital Control Systems including: Programming, Engineering, Field Supervision, and Installation. Specialists shall present factory training certification of the submitted equipment upon request.

C. Governing Code Compliance - The DDC Contractor shall comply with all current governing codes, ordinances and regulations, including UL, NFPA, the local Building Code, NEC, and so forth.

D. FCC Regulation - All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Section 15, Governing Radio Frequency Electromagnetic Interference, and be so labeled.

E. Standard Products
1. Materials and equipment shall be standard products of manufacturer regularly engaged in the manufacturing of such products, using similar materials, design and workmanship. The standard products shall have been in commercial or industrial use for 2 years prior to bid opening. The 2 year use shall include applications of similarly sized equipment and materials used under similar circumstances. The 2 year experience must be satisfactorily completed by a product which has been sold on the commercial market through advertisements, manufacturer s catalogs, or brochures.

2. The equipment items shall be supported by a service organization.

F. Nameplate and Tags
1. Nameplates bearing legends as shown and tags bearing device unique identifiers as shown shall be engraved or stamped. Nameplates shall be permanently attached to HVAC control panel doors.

2. For each field mounted piece of equipment, not in a finished area, a plastic or metal tag with equipment name and point identifier shall be attached.

G. Verification of Dimensions - The contractor shall become familiar with all details of the work, shall verify all dimensions in the field, and shall advise the Contracting Officer of any discrepancy before performing the work.

H. Drawings - Because of the small scale of the drawings, it is not possible to indicate all offsets, fittings, and accessories that may be required. The Contractor shall carefully investigate the mechanical, electrical, and finish conditions that could affect the work to be performed, and shall finish all work necessary to meet such conditions.

I. Modification of References - The advisory provision in ASME B31.1 and NFPA 70 shall be considered mandatory. Substitute the work shall for should wherever it appears and interpret all references to the authority having jurisdiction and owner to mean the Contracting O fficer.

1.07 WORK INCLUDED
A. Installation of Direct Digital Control (DDC) System

1. The DDC Contractor shall furnish and install a complete Direct Digital Control (DDC) System for all mechanical systems and other facility systems as included in the project documents. The DDC system will provide the functional features as defined in Part 1 - General Requirements, Part 2 - Products, and Part 3 - Execution of these Specifications. The DDC Contractor shall provide a complete and operational system to perform all sequences of operations stated within Part 3 or shown on the control drawings.

2. The work under this Section shall include all materials and labor to perform all work required for the installation of the DDC as specified.

3. The drawings and specifications are complementary to one another - meaning that what is called for on one is to be considered called for in both. Where conflicts exists between the specifications and/or drawings, the more stringent requirement shall apply.

4. The DDC Contractor shall be responsible for field verification of site conditions and for gathering all necessary field data for all items to be provided under this contract prior to submitting his or her bid.

5. Where work specified under other Sections of this Specification connects to equipment or systems that are listed and described in this Section, the DDC Contractor shall provide proper connection(s) to such equipment including trade coordination.

1.08 COORDINATION

A. Divisions

1. The DDC Contractor shall cooperate with other divisions performing work on this project as necessary to achieve a complete and neat installation. The Contractor shall also consult the drawings and specifications of all trades to determine the nature and extent of others work.

2. Contractors, Sub-contractors, Employees - It will be the duty of this Contractor to work in cooperation with other contractors, and with other sub-contractors and employees, rendering assistance and arranging his or her work so that the entire project

1.09 MANUALS

A. All manuals shall be provided in hard copy format or on a single Compact Disk (CD) as part of an on-line documentation system through the operator workstation.

PART 2 PRODUCTS

2.01 Y2K COMPLIANT PRODUCTS

A. Provide computer controlled facility components, specified in this section, that are Year 2000 compliant (Y2K). Computer controlled facility components refers to software driven technology and embedded microchip technology. This includes, but is not limited to, programmable thermostats, HVAC controllers, utility monitoring and control systems, alarms, and other facilities

control systems utilizing microcomputer, minicomputer, or programmable logic controllers.

2.02 SYSTEM ARCHITECTURE

A. First Tier Network

1. The first tier network shall be based on a PC industry standard of Ethernet TCP/IP, or ARCnet. PC Workstation LAN controller cards shall be standard off the shelf products available through normal PC vendor channels.

2. The DDC system shall network multiple operator workstations, network controllers, system controllers, and application-specific controllers. The first tier network shall provide communications between operator workstations and first tier DDC (Direct Digital Control) controllers.

3. The first tier network shall operate at a minimum communication speed of 2.5 M baud, with full peer-to-peer network communication.

4. Network Controllers shall reside on the first tier.

B. First Tier Network Protocol Integration

1. The protocol used between two different vendor systems will be BACnet over Ethernet and comply with the ASHRAE BACnet standard 135-1995.

2. The system installed under this contract shall allow bi-directional communications between the owner s designated host system or a BACnet system over an Ethernet TCP/IP data link, or ARCnet. Supported media shall include fiber, 10base2, and 10baseT.

3. A complete Protocol Implementation Conformance Statement (PICS) shall be provided for all BACnet system devices.

4. The ability to share data and change of state (COS) between the owner s designated host system and the system installed under this contract shall be provided.

C. Second Tier Network

1. The second tier network is used to communicate between the first tier DDC controllers and field controllers.

2. Second tier networks shall utilize either Peer-to-Peer, Master-Slave, or Supervised Token Passing communications orr LONWORKS.

D. Second Tier Controller Protocol Integration

1. Hardwired
   a. Analog and digital signal values shall be passed from one system to another via hardwired connections.
   b. There will be one separate physical point on each system for each point to be integrated between the systems.
   c. Analog points will be 4-20 mA signals originating at the from system and being received by the to system .

d. Digital points will be dry contact signals originating at the from system and being received by the to system.

2. Direct Protocol
   a. The DDC system shall include appropriate hardware equipment and software to allow data communications between the DDC system and 3rd party manufacturers control panels. The DDC shall receive, react to, and return information from multiple building systems, variable frequency drives, power monitoring systems, etc.
   b. All data required by the application shall be mapped into the First Tier Network DDC Controllers database, and shall be transparent to the operator.
   c. Point inputs and outputs from the third-party controllers shall have real-time interoperability with DDC software features such as: Control Software, Energy Management, Custom Process Programming, Alarm Management, Historical Data and Trend Analysis, Totalization, and Dial-Up and Local Area Network Communications.
   d. Integration shall be via RS-232 or RS-485 technologies.
   e. The system operator shall have the ability to verify, and diagnose communication messages and point information between third-party controllers and the DDC system.

SPECIFIER'S NOTE: The Consultant shall show the minimum number of digital controllers for the HVAC system on the project drawings.

2.03 DDC SYSTEM

A. Provide a DDC system as a distributed control system. The system shall have stand-alone digital controllers, a communications network (new or existing), and a separate workstation computer with workstation software.

B. Provide an operator programmable system, based on the user applications, to perform closed-loop, modulating and/or on-off control of building equipment. Connect all digital controllers through the communication network to share common data and report to workstation computers. The workstation computers will be capable of being programmed to supervise the digital controllers. The control system shall be capable of down-loading and up-loading of programs between the workstation and the digital controllers.

C. Provide the quantity of digital controllers indicated on the drawings that will perform required climate control, energy management, and alarm functions. The quantity of controllers shall be no less than the number shown on drawings. All material used shall be currently in production.
   1. Direct Digital Controllers - DDC hardware shall be UL 916 rated.
      a. Distributed Control - Apply digital controllers in a distributed control manner.
      b. Environmental Operating Limits - Provide digital controllers that operate in environmental conditions between 32 and 120 degrees Fahrenheit.
      c. Stand-Alone Control - Provide stand-alone digital controllers.
      d. Internal Clock - Provide clock with each controller on the first tier local area network (LAN) and shall have its clock backed up by a

battery or capacitor with sufficient capacity to maintain clock operation for a minimum of 72 hours during a line power outage.

e. Memory -
   1) Provide sufficient memory for each controller to support required control and communication functions.
   2) Memory Protection: Programs residing in memory shall be protected either by using EEPROM or by an uninterruptible power source (battery or uninterruptible power supply (UPS)). The backup power source shall have sufficient capacity to maintain volatile memory in event of an AC power failure. Where the uninterruptible power source is rechargeable (a rechargeable battery), provide sufficient capacity for a minimum of seventy-two hours back-up. The rechargeable power source shall be constantly charged by charging circuitry while the controller is operating under normal line power. Where a nonrechargeable power source is used, provide sufficient capacity for a minimum of two years accumulated power failure. Batteries shall be designed to allow replacement without soldering.

f. Inputs - Provide input function integral to the direct digital controller. Provide input type as required by the DDC design.
   1) Analog Inputs: Allowable input types are three wire 100 ohm or higher platinum RTD s, stable 10,000 ohm thermistors, 0-10 VDC and 4 to 20 ma. Thermistor and direct RTD inputs must have appropriate conversion curves stored in controller software or firmware. Analog to digital (A/D) conversion shall be a minimum of 10 bit resolution.
   2) Digital Inputs: Digital inputs shall sense open/close, on/off, or other two state indications.

g. Outputs - Provide output function integral to the direct digital controller. Provide output type as required by the DDC design. Insure that output of controllers are compatible with controlled devices.
   1) Analog Outputs: Provide controllers with a minimum output resolution of 8 bits. Output shall be 4 to 20 ma or 3 to 15 psi or 0-10 VDC. Each pneumatic output shall have feedback for monitoring of the actual pneumatic signal. Feedback shall be integral to the output function.
   2) Digital Outputs: Provide contact closure with contacts rated at a minimum of 1 ampere at 24 volts.

h. PID Control - Provide controllers with proportional, proportional plus integral, and proportional plus integral plus derivative control capability. Terminal controllers are not required to have the derivative component.

i. Digital Controller Networking Capabilities - The upper level digital controllers shall be capable of being networked with other similar upper level controllers. Upper level controllers shall also be capable of communicating over a network between buildings.

j. Communications Ports
   1) Controller-to-Controller LAN Communications Ports: Controllers in the building DDC system shall be connected in a communications network. Controllers shall have controller to controller communication ports to both peer controller (lower

level controller). Network may consist of more than one level of local area network and one level may have multiple drops. Communications network shall permit sharing between controllers of sensor and control information, thereby allowing execution of dynamic control strategies and coordinated response to alarm conditions.

2) On-Site Interface Ports: Provide a RS-232, RS-485, or RJ-11, or RJ-45 communications port for each digital controller that allows direct connection of a computer or hand held terminal and through which the controller may be fully interrogated. Controller access shall not be limited to access through another controller. On-site interface communication ports shall be in addition to the communications port(s) supporting controller to controller communications. Communication rate shall be 56K Baud minimum. Every controller on the highest level LAN shall have a communications port supporting direct connection of a computer; a hand held terminal port is not sufficient. By connecting a computer to this port, every controller in the direct digital control system shall be able to be fully interrogated and programmed. The following operations shall be available: downloading and uploading control programs, modifying programs and program data base, and retrieving or accepting trend reports, status reports, messages, and alarms.

3) Remote Work Station Interface Port: Provide one additional direct connect computer port in each DDC system for permanent connection of a remote operator s workstation, unless the workstation is a node on the LAN. All operations possible by directly connecting aa computer to a controller at the highest level LAN shall be available through this port.

4) Telecommunications Interface Port: Provide one additional telecommunications port in each DDC system permitting remote communications via telephone. All operations possible by directly connecting a computer to a controller at the highest level LAN shall be available through the telecommunications port. A telecommunications port provided on a digital controller shall be in addition to the port required for directly connecting a computer to the controller. Telecommunication baud rate shall be 96K minimum.

k. Modem - Provide one modem per DDC system to communicate between the digital control system and the workstation.

l. Digital Controller Cabinet - Each digital controller cabinet shall protect the controller from dust and be rated NEMA 1, unless specified otherwise.
Controller cabinets, or enclosures the controller s is mounted in shall be provided with a lock.

m. Main Power Switch - Each controller on the highest level LAN shall have a main power switch for isolation of the controller from AC power. The switch shall be protected from tampering within the DDC cabinet.

2. Terminal Control Units

a. TCU s shall be manufactured by the same company as the digital controllers.
b. TCU s shall automatically start-up on return of power after a failure, and previous operating parameters shall exist or shall be automatically downloaded from a digital controller on a higher level LAN.
c. TCU s do not require an internal clock, if they get time information from the digital controller.

3. DDC Software - Software resides in the digital controllers and performs control sequences.
   a. Sequence of Control - Provide, in the digital controllers, software to execute the sequence of control. Provide sequences of control written in both text and graphic format.
   b. Database Modification - Provide software to modify the control program database. Database modification shall be accomplished through connected computer or hand held terminal or through a keypad integral to the controller. Database modification shall be accomplished without having to make changes directly in line-by-line programming. As a result of this requirement, when the control program is of the line-by-line type, database parameters in the following list that take real number values shall require assignment of variable names so parameters can be changed without modifying the line-by-line programming. Alternatively, block programming languages shall provide for modification of these database parameters in fill-in-the-blank screens. The following shall be modifiable in this way:
      1) Setpoints
      2) Deadband limits and spans
      3) Reset schedules
      4) Switchover points
      5) PID gains and time between control output changes
      6) Time
      7) Timed local override time
      8) Occupancy schedules
      9) Holidays
      10) Alarm points, alarm limits, and alarm messages
      11) Point definition database
      12) Point enable, disable, and override
      13) Trend points, trend intervals, trend reports
      14) Analog input default values
      15) Passwords
      16) Communications parameters including network and telephone communications setups
   c. Differential - Where equipment is started and stopped or opened and closed in response to some analog input such as temperature, pressure, or humidity, include a differential for the control loop to prevent short cycling of equipment.
   d. Motor and Flow Status Delay - Provide an adjustable delay between when a motor is commanded on or off and when the control program looks to the motor or flow status input for confirmation of successful execution of the command.

e. Runtime Accumulation - Provide resettable run time accumulation for each controlled electrical motor.

f. Timed Local Override - Provide user definable adjustable run time for each push of a momentary contact timed local override. Pushes shall be cumulative with each push designating the same length of time. Provide a user definable limit on the number of contact closures summed, such as 6, before the contact closures are ignored. Timed local overrides are to be disabled during occupancy periods.

g. Time Programs - Provide programs to automatically adjust for leap years, and make daylight savings time and standard time adjustments.

h. Scheduling
   1) Each control output point shall be schedulable and its operation based on time of day, day of week, and day of year. Output points may be associated into groups. Each group may be associated with a different schedule. Changing the schedule of a group shall change the schedule of each point in the group. Points may be added to and deleted from groups. Groups may be created and deleted by the operator.
   2) Provide capability that will allow current schedules to be viewed and modified in a seven day week format. When control program does not automatically compute holidays, provide capability to allow holiday schedules to be entered one full year at a time.

i. Point Override - I/O and virtual points shall be able to be software overridden in the software and commanded to any possible value from the main building digital controller.

j. Alarming - I/O points and virtual points shall be alarmable. Alarms may be enabled and disabled for every point. Alarm limits shall be adjustable on analog points. Controllers connected to an external communications device such as a printer, terminal, or computer, shall download alarm and alarm message when alarm occurs. Otherwise alarms will be stored and automatically downloaded when a communications link occurs. The following conditions shall generate alarms:
   1) Motor is commanded on or off but the motor status input indicates no change
   2) Room temperature, humidity, or pressure strays outside selectable limits
   3) An analog input takes a value indicating sensor failure
   4) A module is dead to the LAN
   5) A power outage occurs

k. Messages - Messages shall be operator defined and assigned to alarm points. Messages shall be displayed when a point goes into alarm.

l. Trending - DDC system shall have the capability to trend I/O and virtual points. Points may by associated into groups. A trend report may be set up for each group. The period between logging consecutive trend values shall range from one minute to 60 minutes at a minimum. Trend data type shall be selectable as either averages over the logging period or instantaneous values at the time of logging. The minimum number of consecutive trend values stored at one time shall be 30 per variable. When trend memory is full, the

most recent data shall overwrite the oldest data. Trend data shall be capable of being uploaded to computer. Trend data shall be available on a real time basis; trend data shall appear either numerically or graphically on a connected computer s screen as the data being processed from the DDC system data environment. Trend reports shall be capable of being uploaded to computer disc and archived.

m. Status Display - Current status of I/O and virtual points shall be displayed on command. Points shall be associated into functional groups, such as all the I/O and virtual points associated with control of a single air handling unit, and displayed as a group, so the status of a single mechanical system can be readily checked. A group shall be selectable from a menu of groups having meaningful names; such as AHU-4, Second Floor, Chiller System, and other such names.

n. Diagnostics - Each controller shall perform self-diagnostic routines and provide messages to an operator when errors are detected. DDC system shall be capable of recognizing a nonresponsive module on a LAN. The remaining, responsive modules on a LAN shall not operate in a degraded mode.

o. Power Loss - In event of a power outage, each controller shall assume a disabled status and outputs shall go to an user definable state. Upon restoration of power, DDC system shall perform an orderly restart, with sequencing of outputs.

p. Program Transfer - Provide software for download of control programs and database from a computer to controllers and upload of same to computer from controllers. Every digital controller in the DDC system shall be capable of being downloaded and uploaded to through a single controller on the highest level LAN.

q. Password Protection - Provide at least three levels of password protection to the DDC system permitting different levels of access to the system.

r. Energy Data Recording - Provide a resettable signal accumulation for each meter at the main building digital controller.

1) Calculate chilled water thermal energy in BTU/HR using chilled water supply temperature and flow and chilled water return temperature signals.

2) Record electrical energy in KWH and electrical demand in KW.

4. Workstation

a. Provide a workstation computer and workstation software installed to provide a interface for monitoring, troubleshooting, and making adjustments to the program or operating parameters of the DDC system from a central location. The workstation shall be capable of accessing all controllers, including TCU s, in the DDC system. DDC system shall routinely operate stand-alone on a continuous basis without connection to the workstation. Information at the workstation is not required for day to day operations at the direct digital controllers.

b. Hardware - All workstation computer hardware equipment and peripherals shall be recommended by the DDC system manufacturer. The workstation shall be configured to operate according to the DDC system manufacturer s specifications.

Workstation hardware shall be configured to allow operation of software, uploading and downloading of programs, and creation of graphics. At a minimum the workstation hardware shall consist of:

1) Workstation
   450 MHZ Pentium II processor
   6.4 GB HHD minimum
   64 MB of EDO Ram
   Enhanced IDE (EIDE) controller
   3.5", 1.44 MB Floppy Drive
   32 X CD Rom
   128-bit PCI Graphics accelerator or better w/ 2 MB of Video memory with upgradability to at least 8 MB
   10/100BT Network Interface card
   Keyboard
   Flash BIOS, PnP 1.0a, PCI BIOS 2.1, DMI 2.0 compliant, Y2K compliant
   Pre Installed Windows NT 4.0
   Sound blaster compatible audio with speakers (internal)
   17 inch Monitor (<0.28 mm Dot Pitch & 0.25 Aperture Grill Pitch, 1024x768 at Non-Interlaced 85 Hz or greater, Plug and Play Compatible, Energy Star Compliant)
   Y2K Compliant
   DMI 2.0 compliant
   Three (3) Year Warranty
   Warranty Label
   On-Line Asset Reporting
   OEM or Contractor provide CD-ROM containing software (i.e. operating system/application software) provided on hard drive at time of purchase
   OEM or Contractor provides user s manual for each type of hardware
   Mouse
   Modem; 56k Baud
   Printer; color inkjet
   110 volt terminal strip with surge protection.

c. Software - Workstation software shall be recommended and supported by the DDC system manufacturer and configured to operate according to the DDC system manufacturer s specifications. Workstation software shall permit monitoring and troubleshooting of the DDC system. Workstation software permits modification of the controller database and control programs. Operations shall be menu selected. Menu selections shall be made with a mouse.

   1) Menu System: Menu system shall allow an operator to select a particular function or access a particular screen through successive menu penetration.
   2) Controller Data Base Modification: The workstation software shall be an interface for performing capabilities specified in paragraph entitled DDC Software and available through direct connection of a computer to a digital controller. Database modification shall require only that an operator fill in the blank for that parameter on a screen requesting the information in plain language. Database modifications shall

be automatically downloaded to the appropriate controllers at operator request.

3) Program modification: For systems using a line-by-line programming language, provide an off-line text editor, similar to BASIC program editor, permitting modification of controller resident control programs. For systems using block programming languages provide a capability for linking blocks together to create new programs or modify existing programs. Program modifications shall be automatically downloaded to the appropriate controllers at operator request.

d. Graphic-Based Software - The intent of graphic-based software is to provide an ergonomic interface to the DDC system that encourages effective and efficient interaction with the system. Graphic-based software shall provide graphical representation of the building, the buildings mechanical systems, and the DDC system. The current value and point name of every I/O point shall be shown on at least one graphic and in its appropriate physical location relative to building and mechanical systems.

1) Graphics shall closely follow the style of the control drawings in representing mechanical systems, sensors, controlled devices, and point names.
2) Graphic Title: Graphics shall have an identifying title visible when the graphic is being viewed.
3) Dynamic Update: When the workstation is on-line with the control system, point data shall update dynamically on the graphic images.
4) Graphic Penetration: Provide graphic penetration when the capability exists. For systems without graphic penetration, provide menu penetration for selection of individual graphics to give the same hierarchical affect provided by graphic penetration.
5) Graphic Types: Graphic-based software shall have graphics of the building exterior, building section, floor plans, and mechanical systems. Provide the following graphics:
   a) Building Exterior Graphic: Show exterior architecture, major landmarks, and building number.
   b) Building Section Graphic: Show stacked floors in section graphic with appropriate floor name on each floor.
   c) Floor Plan Graphics: Provide a single graphic for each floor, unless the graphic will contain more information that can reasonably be shown on a single graphic. Each heating or cooling zone within a floor plan shall have a zone name and its -current temperature displayed within the zone outline. Show each controlled variable in the zone. Provide visual indication for each point that is in alarm.
   d) Mechanical System Graphics: Provide two-dimensional drawings to symbolize mechanical equipment; do not use line drawings. Show controlled or sensed mechanical equipment. Each graphic shall consist of a single mechanical system; examples are a graphic for an air

handling unit, a graphic for a VAV box, a graphic for a heating water system, and a graphic for a chiller system. Place sensors and controlled devices associated with mechanical equipment in their appropriate locations. Place point name and point value adjacent to sensor or controlled device. Provide visual indication of each point in alarm. Condition, such as zone temperature, associated with the mechanical system shall be shown on the graphic. Point values shall update dynamically on the graphic.

6) Graphic Editing - Full capacity as afforded by a draw software package shall be included for operator editing of graphics. Graphics may be created, deleted, and modified, and text added. Provide capability to store graphic symbols in a symbol directory and incorporate these symbols into graphics. A minimum of sixteen colors shall be available.

7) Dynamic Point Editing: Provide full editing capability for deleting, adding, and modifying dynamic points on graphics.

8) Trending: Trend data shall be displayed graphically, with control variable and process variable plotted as functions of time one the same chart. Graphic display of trend data shall be a capability internal to the workstation software and not a capability resulting from download of trend data into a third-party spreadsheet program such as Lotus, unless such transfer is automatic and transparent to the operator, and the third-party software is included with the workstation software package. At the operator s discretion trend data shall be plotted real time.

5. Maintenance Personnel Interface Tools - Provide a notebook computer for field communication with the digital controllers. In addition to changing setpoints, and making operational changes, field personnel shall be able to upload and download programs with the notebook computer.

a. Provide [_____ (___)] laptop computer, necessary software, and direct connection cable to communicate with the digital controllers when directly connected.

b. Provide laptop computer with the following features as a minimum:
366 MHZ Mobile Pentium II processor
32 MB SDRAM
13" TFT XGA 64K color display
4.3 GB HD
PnP, Y2K compliant, flash BIOS
Windows 9x
3 1/4", 1.44 MB Floppy Drive
2 PCMCIA slots (2 type II or 1 type III)
24X CD-ROM
PCM CIA, 56K bps Modem
10B T Network Interface Card
64-bit PCI Graphics accelerator with 4MB of Video Memory
Three Year Warranty

c. Recommended by the digital controller manufacturer, and a direct connection cable to communicate with the digital controller.

2.04 SENSORS AND INPUT HARDWARE

A. Field Installed Temperature Sensors

1. Thermistors - Precision thermistors may be used in temperature sensing applications below 200 degrees F. Sensor accuracy over the application range shall be 0.36 degree F or less between the range of 32 to 150 degrees F. Sensor manufacturer shall utilize 100 percent screening to verify accuracy. Thermistors shall be pre-aged, and inherently stable. Stability error of the thermistor over five years shall not exceed 0.25 degree F cumulative. Sensor element and leads shall be encapsulated. Bead thermistors are not allowed. A/D conversion resolution error shall be kept to 0.1 degree F. Total error for a thermistor circuit shall not exceed 0.5 degree F, which includes sensor error and digital controller A/D conversion resolution error. Provide thermistor and digital controller manufacturer documentation and the Contractor s engineering calculations which support the proposed thermistor input circuit will have a total error of 0.5 degree F or less. Provide 18 gage twisted and shielded cable for thermistors.

2. Resistance Temperature Detectors (RTDs) - Provide RTD sensors with 1000 ohm, or higher, platinum element that are compatible with digital controllers. Sensors shall be encapsulated in epoxy, series 300 stainless steel, anodized aluminum, or copper. Temperature sensor accuracy shall be 0.1 percent (1 ohm) of expected ohms (1000 ohms) at 32 degrees F. Temperature sensor stability error over five years shall not exceed 0.25 degree F cumulative. Direct connection of RTDs to digital controllers, without transmitters, is preferred provided controller supports direct connection of RTDs. When RTDs are connected directly to the controller, keep lead resistance error to 0.25 degree F or less. Provide 3 wire sensing circuits to not exceed the 0.25 degree F lead resistance error. Total error for a RTD circuit shall not exceed 0.5 degree F, which includes sensor error, lead resistance error or 4 to 20 milliampere transmitter error, and A/D conversion resolution error. Provide manufacturer documentation and the Contractor s engineering calculations which support the proposed RTD circuit will have a total error of 0.5 degree F or less for the specified application.

   a. Wiring - Provide 18 gage twisted and shielded pair cable for direct connected RTDs. Provide 18 gage twisted and shielded pair cable for RTDs using 4 to 20 milliampere transmitters.
   b. Transmitters - Provide 4 to 20 milliampere transmitters for RTDs where Digital controllers do not support direct connection of RTDs to controllers; Digital controllers do not meet temperature resolution requirement of 0.5 degree F

3. Temperature Sensor Details
   a. Room: Conceal element behind protective cover matched to the room interior. Room temperature sensor shall have integral pushbutton, digital input to the controller for system override, and a setpoint adjustment, analog input to the controller. Digital sensors that communicate directly with the terminal control unit are acceptable. Provide a connection to allow interrogation of the digital controller.

b. Duct Averaging Type: Continuous averaging RTDs for ductwork applications shall be 1 foot in length for each 4 square feet of ductwork cross-sectional area with a minimum length of 6 feet. Probe type duct sensors of one foot length minimum are acceptable in ducts 12 feet square and less.

c. Immersion Type: 3 inches and 6 inches where needed total immersion for use with sensor wells, unless otherwise indicated.

d. Sensor Wells: Brass materials; provide thermal transmission material compatible with the immersion sensor. Provide heat-sensitive transfer agent between exterior sensor surface and interior well surface.

e. Outside Air Type: Provide element on the buildings north side with sunshade to minimize solar effects. Mount element at least 3 inches from building outside wall. Sunshade shall not inhibit the flow of ambient air across the sensing element. Shade shall protect sensing element from rain.

B. Transmitters - Transmitters shall have 4 to 20 ma, or 0-10 VDC output linearly scaled to the temperature, pressure, humidity, or flow range being sensed. Transmitter shall be matched to the sensor, factory calibrated, and sealed. Total error shall not exceed 0.1 percent of 20 milliampere (0.02 milliampere) at any point across the 4 to 20 ma span. Supply voltage shall be 24 volts ac or dc. Transmitters shall have non-interactive offset and span adjustments. For temperature sensing, transmitter stability shall not exceed 0.05 degree F a year.

1. Spans and Ranges - Transmitter spans or ranges shall be the following and shall be suitable for the application:

a. Temperature:

1) 50 degree F span: Room, chilled water, cooling coil, discharge air, return air sensors

2) 100 degree F span: Outside air, hot water, heating coil discharge air, mixed air sensors

3) 200 degree F span: High temperature hot water, heating hot water, chilled/hot water system sensors

b. Pressure

1) 0 to 100 psi differential: Water differential range

2) 0 to 5 inches water differential range: Duct static pressure

C. Relative Humidity Transmitters - Provide integral humidity transducer and transmitter. Output of relative humidity instrument shall be a 4 to 20 milliampere or 0 to 10 VDC signal proportional to 0 to 100 percent relative humidity input. Accuracy shall be 2 percent of full scale within the range 20 to 80 percent relative humidity. Sensing element shall be chilled mirror type, polymer, or thin film polymer type. Supply voltage shall be 24 VDC. Transmitter shall meet specified requirements.

D. Pressure Transmitters - Provide integral pressure transducer and transmitter. Output of pressure instrument shall be a 4 to 20 milliampere or 0 to 10 VDC signal proportional to the pressure span. Span shall be as specified. Accuracy shall be 1.0 percent. Linearity shall be 0.1 percent. Supply voltage shall be 24 VDC. Transmitter shall meet specified requirements.

E. Current Transducers - Provide current transducers to monitor amperage of motors. Select current transducer range for normal amperage to be above 50 percent of the range. Current transducers shall have an accuracy of 1 percent and a 4 to 20 milliampere output signal.

F. Input Switches
   1. Differential Static Pressure Switch - Provide diaphragm type differential static pressure switches for binary (two position) operation as specified in sequence of operation. Devices shall withstand pressure surges up to 150 percent of rated pressure. Contacts shall be single pole double throw and switch may be wired for normally open or normally closed operation. Trip set point shall be adjustable. Pressure switch shall be sized so that operating pressure trip point is approximately midpoint of pressure switch adjustable range. Repetitive accuracy shall be 2 percent.

   2. Induced Current Operated Solid State Switches - Provide adjustable ranging to monitor continuous loads up to 200 amperes. Switch shall indicate whether it is normally open or normally closed. Limit off-state leakage to 2 milliampere or less.

   3. Timed Local Override - Provide momentary contact push button override with override time set in controller software. Provide to override DDC time of day program and activate occupancy program for assigned units. Upon expiration of override time, the control system shall return to time-of-day program. Time interval for the length of operation shall be software adjustable and shall expire unless reset.

G. CO2 sensors: Provide CO2 sensors with integral transducers. Output signal shall be 4 to 20 mA or 0-10 VDC. Accuracy shall be +/- 5 percent

H. Energy Metering
   1. Electric Meters - Provide kilowatt-hour (kWh) meter for building as indicated. Integrate electric meter signal into DDC system.

   2. Meter: ANSI C12.10. Provide watt-hour meter and socket corresponding to the ratios of the current transformers and transformer secondary voltage. Meter shall be selected for -volt, three-phase, three four-wire wye delta system, three-element type with three current transformers. Meters shall be complete with a box mounted socket having automatic circuit closing bypass. Provide watt-hour meter with not less than four pointer-type kWh registers, provisions for pulse initiation, and a universal Class 2 indicating maximum kW demand register, sweep pointer indicating type, with a 15 30 60 -minute interval. Meter accuracy shall be within plus or minus one percent. The correct multiplier shall be provided on face of meter.

   3. Current Transformer: ANSI C57.13. Provide three current transformers with 600-volt insulation, rated for metering with voltage, BIL, momentary, and burden ratings coordinated with the ratings of the associated meters. Provide a butyl molded donut or window type transformers mounted on a bracket to allow secondary cables to connect to the transformer bushings. Identify the wiring of the current transformer secondary feeders to permit field current measurements to be taken with hook-on ammeters.

2.05 OUTPUT HARDWARE

A. Damper - Damper shall conform to SMACNA DCS.

1. A single damper section shall have blades no longer than 48 inches and shall be no higher than 72 inches. Maximum damper blade width shall be 8 inches. Larger sized damper shall be made from a combination of sections.

2. Dampers shall be steel, or other materials where shown. Flat blades shall be made rigid by folding the edges. Blades shall be provided with compressible seals at points of contact. The channel frames of the dampers shall be provided with jamb seals to minimize air leakage. Dampers shall not leak in excess of 20 cfm per square foot at 4 inches water gage static pressure when closed. Seals shall be suitable for an operating temperature range of minus 40 degrees F to 200 degrees F. Dampers shall be rated at not less than 2000 fpm air velocity. All blade-connecting devices within the same damper section will not be located directly in the air stream. Damper axles shall be 0.5 inch (minimum) plated steel rods supported in the damper frame by stainless steel or bronze bearings. Blades mounted vertically shall be supported by thrust bearings. Pressure drop through dampers shall not exceed 0.04 inch water gage at 1000 fpm in the wide open position. Frames shall not be less than 2 inches in width. Dampers shall be tested in accordance with AMCA 500.

3. Operating links external to dampers (such as crankarms, connecting rods, and line shafting for transmitting motion from damper actuators to dampers) shall withstand a load equal to twice the maximum required damper-operating force. Rod lengths shall be stainless steel. Working parts of joints and clevises shall be brass, bronze, or stainless steel. Adjustments of crankarms shall control the open and closed position of dampers.

B. Valves

1. Valve Assembly - Valves shall have stainless steel stems. Valve bodies shall be designed for not less than 125 psig working pressure or 150 percent of the system operating pressure, whichever is greater. Valve leakage rating shall be 0.01 percent of rated Cv. Class 125 copper alloy valve bodies and Class 150 steel or stainless steel valves shall conform to ASME/ANSI B16.5 as a minimum. Cast iron valve components shall conform to ASTM A 126 Class B or C as a minimum.

2. Butterfly Valve Assembly - Butterfly valves shall be threaded lug type suitable for dead-end service and for modulation to the fully closed position, with noncorrosive discs, stainless steel shafts supported by bearing, and EPDM seats suitable for temperatures from minus 20 degrees F to plus 250 degrees F. Valves shall have a manual means of operation independent of the actuator.

3. Three-Way Valves - Three-Way valves shall have equal percentage characteristics.

4. Valves for Chilled Water Service - Bodies for valves 1-1/2 inches and smaller shall be brass or bronze, with threaded or union ends. Bodies for valves from 2 inches to 3 inches inclusive shall be of brass, bronze or iron. Bodies for 2 inch valves shall have threaded ends. Bodies for valves from 2-1/2 to 3 inches shall have flanged-end connections. Internal valve trim shall be brass or bronze except that valve stems may be Type 316 stainless steel. Water valves shall be sized for a 3 psi differential through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow. Valves 4 inches and larger shall be butterfly valves.

5. Valves for hot water service below 250 Degrees F
   a. Bodies for valves 1-1/2 inches and smaller shall be brass or bronze with threaded or union ends. Bodies for valves larger than 2 inches shall have flanged-end connections. Water valves shall be sized for a 3 psi differential through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow.
   b. Internal trim, including seats, seat rings, modulation plugs, aand springs, of valves controlling water hotter than 210 degree F shall be Type 316 stainless steel.
   c. Internal trim for valves controlling water 210 degrees F or less shall be brass or bronze.
   d. Non-metallic parts of hot water control valves shall be suitable for a minimum continuous operating temperature of 250 degrees F above the system design temperature, whichever is higher.

C. Actuator - Provide electric type with spring return so that, in the event of power failure, actuators shall fail safe in either the normally open or normally closed position as specified. Actuators shall be quiet operating and function properly within the range of 85 to 110 percent of the motive power. Provide a minimum of one actuator for each damper.
   1. Electric Actuators - Provide direct drive electric actuators for all damper control applications. When operated at rated voltage, each operator shall be capable of delivering the torque required for continuous uniform movement of the valve or damper and shall have end switch to limit travel or shall withstand continuous stalling without damage. Operators shall function properly with range of 85 to 110 percent of line voltage. Provide gears of steel or copper alloy. Fiber or reinforced nylon gears may be used for torques less than 16 inch pounds. Provide hardened steel running shafts in sleeve bearing of copper alloy, hardened steel, nylon, or ball bearing. Provide two-position operators of the single direction, spring return, or reversing type. Provide proportioning operators capable of stopping at all points in the cycle and starting in either direction, from any point. Provide reversing and proportioning operators with limit switches to limit travel in either direction unless operator is stall type. Equip valve operators with a force limiting device such as spring yield so that, when in a relaxed position, device shall maintain a pressure on valve disc equivalent to system pressure at valve. Provide reversible shaded pole, split capacitor, synchronous, or stepped type electric motors.

D. Output Switches

1. Control Relays - Shall be double pole, double throw (DPDT), UL listed, with contacts rated to the application, and enclosed in a dustproof enclosure. Equip with a light indicator which is lit when coil is energized and is off when coil is not energized. Relays shall be socket type, plug into a fixed base, and be replaceable without need of tools or removing wiring.

2.06 ELECTRICAL POWER AND DISTRIBUTION

Provide a source 120 volts or less, 60 Hz, two-pole, three wire with ground. Devices shall be UL listed or FM approved.

A. Transformers - Transformers shall conform to UL 506. Power digital controllers on the highest level LAN from dedicated circuit breakers. Transformers for digital controllers serving terminal equipment on lower level LANs shall be fed from the fan motor leads or fed from the nearest distribution panelboard or motor control center, using circuits provided for the purpose. Provide a fuse cutout on the secondary side of the transformer.

B. Surge Protection - Surge and transient protection consist of devices installed externally to digital controllers.

1. Power Line Surge Protection - Surge suppressors external to digital controller, shall be installed on all incoming AC power. Surge suppressor shall be rated by UL 1449, and have clamping voltage ratings below the following levels:
   a. Normal Mode (Line to Neutral): 350 volts
   b. Common Mode (Line to Ground): 350 volts
   c. Telephone and Communication Line Surge Protection - Protected from surges. Metal oxide varistor (MOV) protection, rated for the application, shall be installed at the equipment. Additional protection, gas tubes rated for the application, shall be installed within 3 feet of the building cable entrance or within 3 feet of the telephone company s network interface.

C. Wiring - Provide complete electric wiring for DDC system, including wiring to transformer primaries. Control circuit conductors which run in the same conduit as power circuit conductors shall have the same insulation level as power circuit conductors. Circuits operating at more than 100 volts shall be in accordance with Section 16402, Interior Distribution Sy stem. Circuits operating at 100 volts or less shall be defined as low voltage and shall be run in rigid or flexible conduit, metallic tubing, metal raceways or wire trays, armored cable, or multiconductor cable. Use multiconductor cable for concealed accessible locations only. Provide circuit and wiring protection as required by NFPA 70. Aluminum-sheathed cable or aluminum conduit may be used but shall not be buried in concrete. Wiring in HVAC plenums shall be in conduit. Protect exposed wiring from abuse and damage.

1. AC Control Wiring - Control wiring for 24 volt circuits shall be insulated copper 18 AWG minimum and shall be rated for 300 VAC service. Wiring for 120 volt shall be 14 AWG minimum and shall be rated for 600 VAC service.

2. Analog Signal Wiring - Analog signal wiring for analog inputs and analog outputs shall be 18 AWG single or multiple twisted pair. Each cable shall

be 100 percent shielded, and have 20 AWG drain wire. Exception is direct connect RTD wiring which shall be single 18 AWG minimum twisted pair, 100 percent shielded, and with 20 AWG drain wire. Each wire shall have insulation rated to 300 VAC. Cables shall have an overall aluminum-polyester or tinned-copper (cable-shield tape), overall 20 AWG tinned copper cable drain wire, and overall cable insulation rated to 300 VAC. Install analog signal wiring in conduit separate from AC power circuits.

2.07 FIRE PROTECTION DEVICES

A. Smoke Detectors - Provide smoke detectors in return and main supply air ducts on downstream side of filters in accordance with NFPA 90A, except as otherwise indicated. Provide UL listed or FM approved detectors for duct installation.

B. Smoke Dampers and Combination Smoke/Fire Dampers - Smoke damper and actuator assembly as required in accordance with NFPA 90A shall meet the Class II leakage requirements of UL 555S. Dampers shall be factory fabricated, galvanized steel or stainless steel with lubricated bearing, linkage, and seals to withstand temperatures from minus 20 to plus 250 degree F. Provide seals that can easily be replaced. Combination smoke/fire dampers shall have UL 1.5 hour rating aand shall be equipped with electric/thermal link which closes damper at 165 degrees F and then automatically resets after normal temperature is restored by cycling damper operator. Equip dampers with pneumatic or electric operators which close smoke dampers tightly when activated.

2.08 INDICATORS

A. Thermometers - Provide thermometers in locations as indicated. Thermometers shall have either 9 inch scales, or 3.5 inch dials and shall have insertion, immersion or averaging elements as indicated. Provide thermowells for liquid sensing applications. Select thermometer ranges so normal temperatures are approxiamately equal to midpoint readings on the scale, unless otherwise stated.

B. Pressure Gages - Provide pressure gages as indicated. Select gage range so normal pressures are approxiamately equal to the midpoint readings on tthe scale, unless otherwise specified. Accuracy shall be plus or minus 2 percent of the range. Gages shall conform to ANSI/ASME B40.1.

1. Gages indicating pneumatic outputs shall have 2 inch diameter faces. Scale shall be 0 to 30 psi, with 1 psi graduations.

2. Gages for low differential pressure measurements shall be 4-1/2 (nominal) size with two sets of pressure taps, and shall have a diaphragm actuated pointer, white dial with black figures, and pointer zero adjustment. Gage shall have ranges and graduations as shown. Accuracy shall be plus or minus 2 percent of scale range.

PART 3 EXECUTION

3.01 INSTALLATION

Perform installation under supervision of competent technicians regularly employed in the installation of DDC systems. Provide components for a complete and operational system.

A. Wiring Criteria
   1. Input/Output identification: Permanently label each field wire, cable, or pneumatic tube at each end with unique identification.

   2. Rigid or flexible conduit shall be terminated at all sensors and output devices.

   3. Surge Protection: Install surge protection no more than three feet from where communication cable enters building.

   4. Grounding: Ground controllers and cabinets to a good earth ground. Ground controller to a ground in accordance with Section 16402, Interior Distribution System. Grounding of the green ac ground wire, at the breaker panel, alone is not adequate. Run metal conduit from controller panels to adequate building grounds. Ground sensor drain wire shields at controller end.

   5. Contractor is responsible for correcting all associated ground loop problems.

B. Digital Controllers
   1. Do not divide control of a single mechanical system such as an air handling unit, boiler, chiller, or terminal equipment between two or more controllers. A single controller shall manage control functions for a single mechanical system. It is permissible, however, to manage more than one mechanical system with a single controller.

   2. Provide digital control cabinets that protect digital controller electronics from dust, at locations shown on the drawings.

   3. Provide a main power switch at each highest level LAN digital controller within controller cabinet.

   4. No multiplexing of points is allowed.

C. Temperature Sensors - Provide temperature sensors in locations to sense the appropriate condition. Provide sensor where they are easy to access and service without special tools. Calibrate sensors to accuracy specified. In no case will sensors designed for one application be installed for another application.
   1. Duct Temperature Sensors
      a. Provide sensors in ductwork in general locations as indicated. Select specific sensor location within duct to accurately sense appropriate air temperatures. Do not locate sensors in dead air spaces or positions obstructed by ducts or equipment. Install gaskets between the sensor housing and duct wall. Seal duct and insulation penetrations.
      b. String duct averaging sensors between two rigid supports in a serpentine position to sense average conditions. Thermally isolate

temperature sensing elements from supports. Provide duct access doors to averaging sensors.

2. Immersion Temperature Sensors - Provide thermowells for sensors measuring temperature in liquid applications or pressure vessels. Locate wells to sense continuous flow conditions. Do not install wells using extension couplings. Where piping diameters are smaller than the length of the wells, provide wells in piping at elbows to effect proper flow across entire area of well. Wells shall not restrict flow area to less than 70 percent of pipe area. Increase piping size as required to avoid restriction. Provide thermowells with thermal transmission material within the well to speed the response of temperature measurement. Provide wells with sealing nuts to contain the thermal transmission material.

3. Outside Air Temperature Sensors - Provide outside air temperature sensors on north side of the building, away from exhaust hoods, air intakes and other areas that may affect temperature readings. Provide sunshields to protect outside air sensor from direct sunlight.

D. Damper Actuators - Actuators shall not be mounted in the air stream.

E. Thermometers - Provide thermometers at locations indicated. Mount thermometers to allow readability when standing on the floor.
   1. Pressure Sensors -
      a. Differential Pressure
         1) General - Install pressure sensing tips in locations to sense appropriate pressure conditions.
         2) Duct Static Pressure Sensing - Locate duct static pressure tip approxiamately two-thirds of distance from supply fan to end of duct with the greatest pressure drop.
         3) Pumping Proof with Differential Pressure Switches - Install high pressure side between pump discharge and check valve.

F. Control Drawings - Post laminated copies of as-built control system drawings in each mechanical room. Provide six (6) sets of as-built drawings to the activity.

3.02 ADJUSTMENTS - Calibrate instrumentation and controls and verify the specified accuracy using test equipment with a test equipment accuracy. Adjust controls and equipment to maintain conditions indicated, to perform functions indicated, and to operate in the sequence specified.

3.03 FIELD QUALITY CONTROL

A. General
   1. Demonstrate compliance of the heating, ventilation, and air conditioning control system with the contract documents. Furnish personnel, equipment, instrumentation, and supplies necessary to perform calibration and site testing. Ensure that tests are performed by competent employees of the DDC system installer or the DDC system manufacturer regularly employed in the testing and calibration of DDC systems.

2. Testing will include the field tests and the performance verification tests. Field tests shall demonstrate proper calibration of input and output devices, and the operation of specific equipment. Performance verification test shall ensure proper execution of the sequence of operation and proper tuning of control loops.

3. Obtain approval of the plan for each phase of testing before beginning that phase of testing. Give to the Engineer written notification of planned testing at least 45 days prior to test. Notification shall be accompanied by the proposed test procedures. In no case will the Contractor be allowed to start testing without written State approval of test procedures. The test procedures shall consist of detailed instructions for complete testing to prove performance of the heating, ventilating and air conditioning system and digital control system.

4. Before scheduling the performance verification test, furnish the field test documentation and written certification to the Contracting Officer that the installed system has been calibrated, tested, and is ready for the performance verification test. Do not start the performance verification test prior to receiving written permission from the Government.

3.04 TRAINING

A. The controls contractor shall provide the following training services:

1. One (1) day of on-site orientation by a field engineer who is fully knowledgeable of the specific installation details of the project. This orientation shall, at a minimum, consist of a review of the project as-built drawings, the control system software layout and naming conventions, and a walk through of the facility to identify panel and device locations.

2. General: Provide training course schedule, syllabus, and training materials 45 days prior to the start of training. Conduct training courses for designated personnel in the maintenance and operation of the HVAC and DDC system. Orient training to the specific system being installed under this contract. Use operation and maintenance manual as the primary instructional aid. Operational and maintenance manuals shall be provided for each trainee with four additional sets, two sets delivered for archiving at the project site, one set for the mechanical contractor, and one set for the design engineer. Training manuals shall include an agenda, defined objectives and a detailed description of the subject matter for each lesson. Furnish audio-visual equipment and all other training materials and supplies. A training day is defined as 8 hours of classroom or lab instruction, including two 15 minute breaks and excluding lunch time, Monday thru Friday, during the daytime shift in effect at the training facility. For guidance, assume the attendees will have a high school education and are familiar with HVAC systems. The minimum amount of training for this project shall be 24 hours.

3. Operator Training: Operator training shall include the detailed review of the control installation drawings, points list, and equipment list. The instructor shall then walk through the building identifying the location of the control devices installed. For each type of systems, the instructor shall demonstrate how the system accomplishes the sequence of operation.

4. From the workstation, the operator shall demonstrate the software features of the system. As a minimum, the operator demonstrate and explain logging on, setting passwords, setting up a schedule, trend, point history, alarm, and archiving the database.

5. Maintenance Training: The system maintenance course shall be taught at the project site within one month after the completion of the operators training. The course shall last for one 8 hour training day. The course shall include answering questions from the last training session, trouble shooting and diagnostics, repair, instructions, preventive maintenance procedures and schedules, and calibration procedures.

3.05 SEQUENCE OF OPERATION - Sequence of operations shall be as indicated.

3.06 COMMISSIONING - The Commissioning Agent shall be responsible for commissioning the DDC system as specified in the commissioning sections of the specification.

3.07 WORKSTATION AND LAPTOP - Computers shall be provided upon project completion.

3.08 SYSTEMS INTEGRATION/DDC SPECIFIC REQUIREMENTS

A. DDC Remote Access - The Direct Digital Control (DDC) system provided shall include the capability for multiple users to access the DDC simultaneously from remote locations. Interface shall be to the entire DDC and provide the capability to monitor all I/O and adjust parameters.

B. Open Systems Integrator

SPECIFIER S NOTE: For CENTRAL CHILLER SYSTEMS, the following shall be added to SECTION 15601 CENTRAL REFRIGERATION EQUIPMENT FOR AIR CONDITIONING:

CHILLER TRANSLATOR/BACnet:

As part of the Chiller Control package provided with the Chiller by the Chiller Manufacturer, provide a communications system that will allow a BACnet-based Direct Digital Control (DDC) system to access each Chiller s Microprocessor/Control Panel s vast arrray of point information (such as pressures, temperatures, status, runtimes, suction, Amps, KW, and others), without installing any duplicate sensors.

The BACnet Chiller translator will communicate to the DDC system bi-directionally, utilizing standard ASHRAE BACnet Protocol, and will allow full Monitoring and Reset comtrol of the Chillers by the BACnet DDC system.

The Chiller Manufacturer is to provide all as necessary to accomplish this Chiller interface, such as complete list of all available Chiller Points, all BACnet Protocol Implementation Conformance Statements (PICS) files, any necessary Software, all necessary Passwords, Labor as needed, aand all interface Hardware as necessary for complete and operational connection to the BACnet DDC System.

1. Chiller Integrator Interface:

a. The BAS system shall include appropriate hardware equipment and software to allow two way data communications between the BAS system and the chiller manufacturer s chiller control panel.
b. It shall be the responsibility of the BAS Contractor to coordinate with the chiller manufacturer to provide a functional data communications connection.
c. All data supported by the chiller communication protocol shall be mapped into the supervisory DDC controller s database and shall be displayed on a chiller data screen at the Operator Workstation and shall be transparent to the operator.
d. The BAS Contractor shall furnish either the OSP or BACnet communications interface as required by the chiller manufacturer.
e. The BAS Contractor shall provide all communications and power wiring and gateway panel installation for the DDC system. The chiller manufacturer shall provide all hardware for connection of the manufacturer s processor.
f. The BAS Contractor shall provide all hardware and software required for the chiller manufacturer s gateway interface.

2. VFD Integrator Interface
a. The BAS system shall include appropriate hardware equipment and software to allow two way data communications between the BAS system and the VFD manufacturer s control panel.
b. It shall be the responsibility of the BAS Contractor to coordinate with the VFD manufacturer to provide a functional data communications connection.
c. All data supported by the VFD communication protocol shall be mapped into the supervisory DDC controller s database and shall be displayed on data screens at the Operator Workstation and shall be transparent to the Operator Workstation and shall be transparent to the operator.
d. The BAS Contractor shall furnish either the OSP or BACnet communications interface as required by the VFD manufacturer.
e. The BAS Contractor shall provide all communications and power wiring and gateway panel installation for the DDC system. The VFD manufacturer shall provide all hardware for connection of the manufacturer s processor.
f. The BAS Contractor shall provide all hardware and software required for the VFD manufacturer s gateway interface.

3. Boiler Integrator Interface
a. The BAS system shall include appropriate hardware equipment and software to allow two way data communications between the BAS system and the Boiler manufacturer s control panel.
b. It shall be the responsibility of the BAS Contractor to coordinate with the Boiler manufacturer to provide a functional data communications connection.
c. All data supported by the boiler communication protocol shall be mapped into the supervisory DDC controller s database and shall be displayed on data screens at the Operator Workstation and shall be transparent to the operator.
d. The BAS Contractor shall furnish either the OSP or BACnet communications interface as required by the Boiler manufacturer.

e. The BAS Contractor shall provide all communications and power wiring and gateway panel installation for the DDC system. The Boiler manufacturer shall provide all hardware for connection of the manufacturer s processor.
f. The BAS Contractor shall provide all hardware and software required for the Boiler manufacturer s gateway interface.

***SPECIFIER S NOTE:** the Consultant Shall Create a Points List on the Drawings and Coordinate the Points List with Each Affected Mechanical Equipment.*

END OF SECTION